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ASX Limited
Exchange Centre
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PRESENTATION
1st EUROPEAN RARE EARTH RESOURCES CONFERENCE (ERES)
MILOS ISLAND GREECE

The Managing Director and CEO of Krucible Metals Limited (“Krucible”, “Company”), Allan Branch, has been invited to present a research paper detailing Krucible’s analysis of the global pricing dynamics of the rare earths industry at the 1st European Rare Earths Resources conference in Greece (ERES). This is the first time Krucible has had an opportunity to present the research to the European audience.

While in Europe Krucible has held discussions with important processing companies concerning processing of its rare earth assets once mining commences.

This material in slide show format was presented recently at the 27th Rare Earths Research Conference 2014 held by the University of Nevada at Reno, where it caught the favourable attention of the US Department of Energy in Pittsburgh and the US Institute of Critical Materials at Ames Laboratories in Iowa.

Following the European conference, the research will then be presented for the first time to the Chinese audience at the Rare Earths 2014 Conference in Chengdu and then distributed at the China Metals Week conference and trade show in Beijing.

Krucible is actively seeking a strategic partner to join in its exciting and innovative rare earths development program.

The work is a key aspect of Krucible’s plans as an emerging rare earths player in Australia and hints at the different approach taken by the Company to ensure profitability when commercialising these globally crucial metals and illustrates why China has failed over the longer term to control world rare earth prices.

Please see the full research paper attached to this announcement.

Sincerely,

Allan Branch
Managing Director and CEO



Global Pricing Dynamics of the Rare Earths Industry Europe

Allan Branch

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Abstract

This research examines the enigma of a market with critical global demand, deliberately controlled geopolitical supply, yet prices which when not depressed are reported as incomprehensible. Scientific interest and funding is dependent on rare earths having a commercial market, so prices are of crucial importance. The results show that regardless of how critical rare earths are, only 5% to 10% are used in defence and aerospace applications, they are almost exclusively used in consumer products, which implies strict price ceilings for components and raw materials. With China supplying 87% of product and 60% of export demand coming from Japan, those two countries essentially define the supply and demand market. Japan primarily manufactures consumer products. The vast majority of demand therefore sits in what is called an elastic market, and the solutions manufacturers use when faced with pricey components in these markets are to find alternative suppliers or to eliminate the need for the components all together. During the search by manufacturers for alternatives, prices usually hike temporarily because it takes time to source alternatives or change production, but then the price settles in a so called shift to a new equilibrium. These dynamics are evident in the historical rare earths market.

Introduction

This economic research was first described on June and July, 2013 on Investointel.com with the subtitle, "Am I the only one who thinks rare earth prices will always be low?"¹ The work was updated in June 2014 comparing predictions with subsequent events and amongst others drew the attention of the USA Critical Materials Institute, suggesting that it would be relevant to European strategies.

Elementary economics states that when a commodity is in crucial demand and supply of that commodity is low or restricted, the price goes up. When entering the rare earths sector in 2012 it was clear to the author that few participants had an answer as to why rare earth prices were not high, and they lamented the fact in vocal frustration².

China has long intended for its essential monopoly of the rare earths elements to allow control of global rare earth prices³. Yet with most of the world's rare earth production in China and their efforts to manipulate prices through rigorous control of supply, prices continue to drop. China has done everything it can think of, stopping or limiting production, eavesdrop on producers, eradicate pirating and refusing supply to some clients. Every now



and then there is a bump and everyone gets excited, but the trend is clear. Rare earths go into energy, space and military sectors, but that accounts for only about 10% of the demand. With China supplying 87% of product (down from as much as 95% with the advent of Lynas and Molycorp) and with as much as 80% of export demand coming from Japan, those two countries, for all intents and purposes, define the supply and demand market.

Japan mainly manufactures consumer products. Regardless of how important rare earths are, they are therefore used almost exclusively in cheap electronic commodities, which have established retail prices and strict ceilings on the cost of components and raw materials. The vast majority of demand therefore sits in what is called an elastic market. An elastic market is one in which high commodity prices are not tolerated. That is because the eventual products are themselves price sensitive, usually consumer products for mass markets.

The two solutions manufacturers use when faced with pricey materials in these markets, are to find cheaper suppliers or to eliminate the need for the material all together. During the search by manufacturers for these alternative solutions, prices do usually hike for a little while because it takes time to source alternatives or retool production lines, but then the price settles back down again and there is a so called shift to a new equilibrium between supply and demand.

Once this erroneous price manipulation fails, then the manipulator generally changes tack attempting to retain or recapture market share. All of these dynamics are clearly evident in the rare earths market^{3,4}.

The results of this research suggest that the rare earths market is entering a final phase, where prices will remain moderate but stable. Business models or projections based on hoped for or sustained high prices are probably doomed, but those companies presenting profits on current prices are probably safe and worth investigating.

Rare Earths, Elastic Markets & Sheep

A global market can sometimes be thought of as a chess game, so when business plans are based on only one side's strategies, the surprises from the other side can be devastating. Since chess is a game between only two players, a less limiting analogy is a large set of simultaneous chess games, with each player constantly looking at other players' moves for inspiration and learning experience. So while China and Japan are playing it out, so are India and Japan, and so are the USA and Canada and Australia and Kazakhstan and so on. While China has focused on its game, the rest of the world has been playing out its games.

The missing factor in much of this, in my opinion, has been the effect of the Global Financial Crisis caused by the housing bubble. Not because of the crisis but because of the bubble.



The GFC is the most recent, most discussed, and most felt global financial fiasco of modern times. I like the historical housing prices in **Figure 1** because it shows the trend lines which predict where the prices will return to once the bubble bursts and the scatter settles down. When the historical rare earth prices chart is examined and compared, it is clear that this has been a bubble too as seen in **Figure 2**

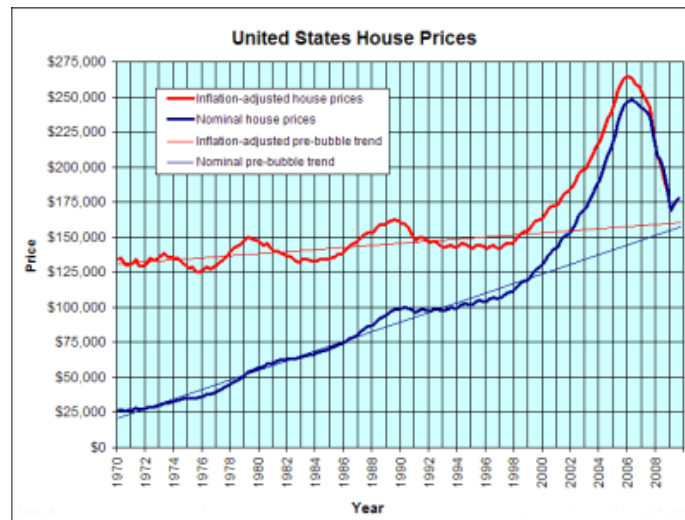


Figure 1: Collapse of the Housing Bubble in 2006 precipitating the Global Finance Crisis.

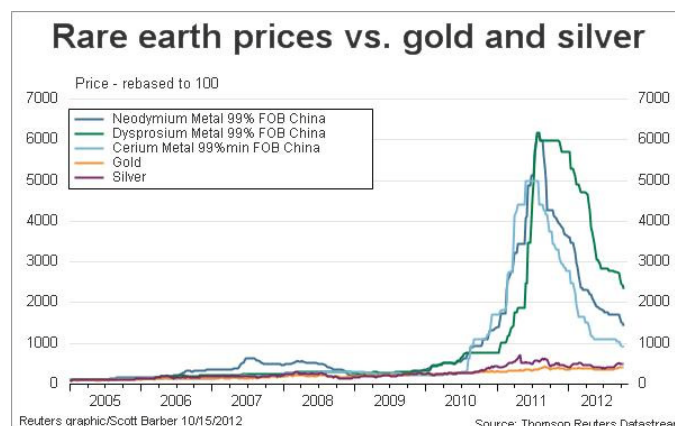


Figure 2: Comparison of housing bubble of Figure 1 and the rare earth prices of 2011 show a distinct similarity suggesting the high rare earth prices were an anomaly and not a new price level.

It is possible that some of the rare earths price hike of 2011 was caused directly or indirectly by the mentality of the GFC. Many independent commentators at the time like Jack Lifton⁵ and Constantine Karayannopoulos⁶ said as much. John Hykawy⁷ was prescient very early in the piece directly linking the rare earth and housing bubbles. Others like Roger Nusbaum⁸, Nick Kurtis⁹ and Mark Smith¹⁰ thought otherwise opining it was a supply and demand thing. Some built their businesses on those opinions.

Figure 3 shows the stages of a modern global market bubble¹¹. A bubble accelerates out of all proportion, bursts, and then settles to where the trend line would naturally come out. House prices skyrocketed, then collapsed below value, and have started to stabilize by climbing back to their normal growth curves, based naturally on capital appreciation and



inflationary indices.

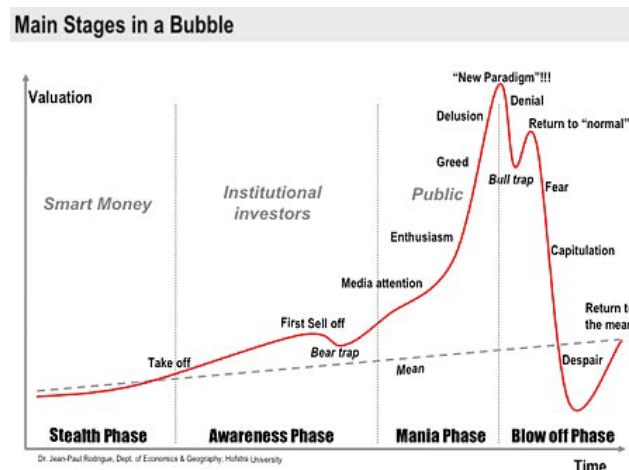


Figure 3: Stylised model of a financial or economic bubble. John-Paul Rodrigue, Department of Economics & Geography Hofstra University 2008¹¹.

The reason that rare earths “will remain moderate and stable” is twofold. Firstly, historical prices have always been moderate. The very long term pricing chart as shown in **Figure 4** shows that they came into their own as a commodity with the invention of the transistor, that there are little surges at times of technological revolution (integrated circuit, microprocessor, internet, ipods), but generally have followed what one would expect for an Elastic Market.



Figure 4: Long term historical rare earth prices.

Secondly, prices now are probably close to or below the trend line, seen in **Figure 5**. There is perhaps an over compensation, so a dampened oscillation back to normal can be anticipated. That is where I think we are now.

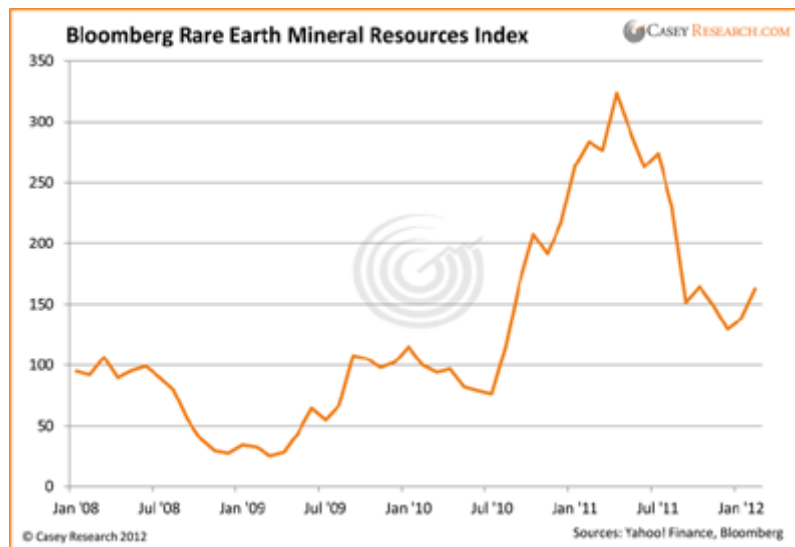


Figure 5: Rare Earth pricing bubble. Bloomberg.

And there is a subtle reason for the oscillation. It is based on the fundamental difference between “Supply” and “Demand”. Demand can be instantaneous: a need, a desire, an opportunity. It is a concept. Supply is a real-world effect, based on physical and practical factors. It takes time to plan production, build factories, develop prototypes, make things. This lag causes interesting phenomena, such as the temporary spike in the first place when manufacturers have no immediate options as they search for alternatives. Afterwards the supply and demand equilibrium is shifted since once a producer finds an alternative to an expensive component, they will rarely go back, even if the price drops. A lesson for China to learn; may have in fact just learnt it.

Supply and Demand is not a snapshot, it is a process in constant flux, always struggling to maintain an equilibrium against the “noise”. Afterwards it will be easy to see what has happened, but in the midst of upheaval, all is speculation.

Bubbles are caused by a mix of avarice and sheep like blind following. What must be kept in mind is the sheer size of the world which in its modern mode is intolerant of exploitation. Giant countries forget their power in a market place is affected by the choices of billions of consumers and a couple hundred chess players.

Rare Earth Prices Will Do Exactly This

Since the advent of the rare earth pricing bubble, which really started to show towards the end of 2010 ending abruptly at the middle of 2011 and which has been in a spiral ever since, there has been speculation about the future prices of these critical metals.

Speculation has taken two basic forms: that which expects or hopes the prices will return to their 2011 highs^{12,13,14} and that which simply despairs about the continued decline in prices¹⁵. The rare observer played it safe¹⁶.

The Author’s article of June 7, 2013, “Rare Earths and Elastic Markets”¹⁷, essentially



dispelled the thought that prices would return to the 2011 highs arguing that those prices were an anomaly. Being a doomsayer is all well and good, but helps no one. If it is true that prices were a bubble, then what would be really helpful would be some prediction of where the prices will finally settle, at what price and when. The author is not the first to see the benefit of this¹⁸.

The first problem in this exercise is to define what one actually means by “rare earth prices.” Even defining “rare earths” is complex enough let alone their prices, given that they are really a disparate group and it is dangerous to bag them together. In fact there is no such thing as a rare earth price. There are 17 rare earths, so there are 17 price trends, and each element can be supplied in several salts, blended or metal form, each with their own pricing trends. Even a so called basket price is dependent on whose basket is being discussed.

Analysis showing rare earths are an elastic markets agreed with the general opinion that at least some rare earths will return to stronger prices eventually. Which ones is another problem to solve. It is not as simple as just separating the light rare earths from the heavy rare earths which is the gut reaction¹⁹. In fact there are contradictory definitions of HREE and LREE just to make it harder, and some reports refer to a middle set which is not officially recognised by the US Geological Survey. And although the HREE are generally the heavier ones from europium to lutetium they include one of the lightest; yttrium. Nothing is straight forward.

Technically the definition of a heavy rare earth, (or a light one), is based on electron configurations on an inner shell affecting its magnetic and orbital radius properties. Because of the sequence as these electrons fill out, it does follow the atomic number more or less, but it is more to do with what the chemical and physical properties are like given the unusual electron configurations. So heavy rare earths do certain things that light ones do not, such as having greater magnetic characteristics, or different crystalline structures in hard metal alloys or silicon structures. Through other cosmic forces, the odd numbered electron configurations make the heavies rarer on earth, but it is the chemical and physical characteristics of the heavies that make them important in today’s technology world and their difficulty in separation (not their prevalence) that makes them expensive.

So relevant factors determining which rare earths will remain at modest prices and which ones are currently undervalued are such things as type of use (commodity or not), rarity or abundance, geopolitical importance, ease of preparation or separation, advent of new processors, changing technology, and substitutability.

The objective here is to work out if some rare earths will soar in price and if so, which ones, to what price and when. There are different ways to approach this problem, but the method chosen is based on the belief that the 2011 prices were a bubble and that bubbles tend to return to earth as an oscillation.

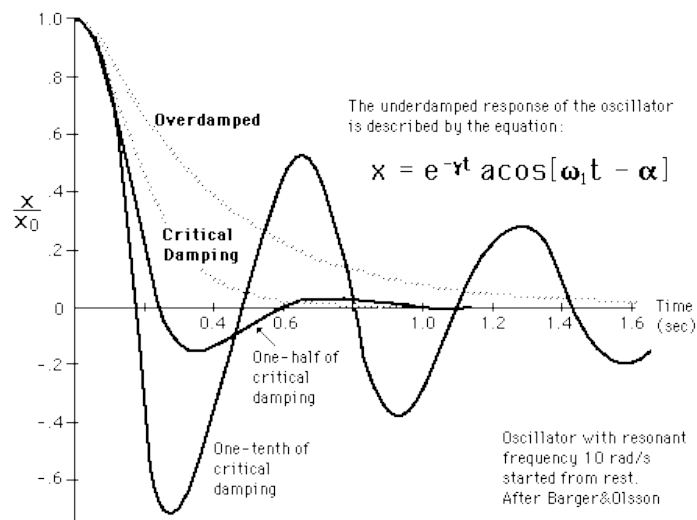


Figure 6: Damped Oscillation.

The mathematics of oscillation can be quite daunting, and using this model requires estimates of the level of damping. Damping is the rate at which an oscillation settles, like a pendulum coming to a stop by itself. High damping means it stops quickly and slight damping means that it takes forever to come to a complete stop. Critical damping is that unique situation where it comes to a stop smoothly, like a car halting at a stop light. It is convenient sometimes to refer to critical, half-critical and quarter-critical damping as seen in **Figure 6**.

It is instructive to compare the half-critical damped curve in **Figure 6** with the recovery stage (return to the mean) of the generic economic bubble curve in **Figure 3**.

This suggests that the recovery from a bubble can be modelled approximately by a damped oscillation. The peak price eventually caves in with everyone following it, until it has over reacted and everyone brings it back, which is the reason for the reference to sheep. What can rarely be determined is the level of damping, so the prices might oscillate for a cycle or two, or if it returns to normal carefully, can be critically or even over damped.

What causes damping in a physical system is a loss of energy, a result of resistance, and there is a conceptual version of resistance happening in an economic bubble too. Oscillations and bubbles start with a push. Eventually there is resistance to the irrationality of the price when it is too high or too low, and things spring back to normal. This is a meeting of human psychology and commercial rationalisation, and is seen in the traditional supply and demand curves. This part of this research will suggest when the price will settle.

The next thing to determine is the base line, and to discover if it is linear, exponential, increasing, decreasing, or what. This part of the exercise will suggest at what price the curve will settle and is akin to the dashed line in **Figure 3**.

Both of these tasks, “when” and “where”, require raw data and Metal-Pages and Gareth Hatch of Technology Metals Research, LLC have been generous enough to provide the necessary data. An example of one heavy rare earth and one light: europium and



praseodymium respectively were chosen for reasons given below. **Figure 7** shows the Chinese FOB prices for these over the last 5 years. The difference in price between a heavy and a light is clearly evident in this figure, which uses the same price axis on the left.

While Eu prices seem to have averaged around \$US500 per ton until early 2011 when the bubble started, and then rose to above \$5,500 at its peak in August 2011, they have been clawing their way back down again to \$883 in June 2013 when the analysis was done and has been kept so that predictions made then can be compared to what has happened since. Although at lower prices, Pr has done the same thing, averaging something like \$30 per ton before, peaking at \$250 also in August 2011 and in July 2013 was at \$74 per ton. Pr did seem to make a false earlier start to its bubble, starting in August 2010.

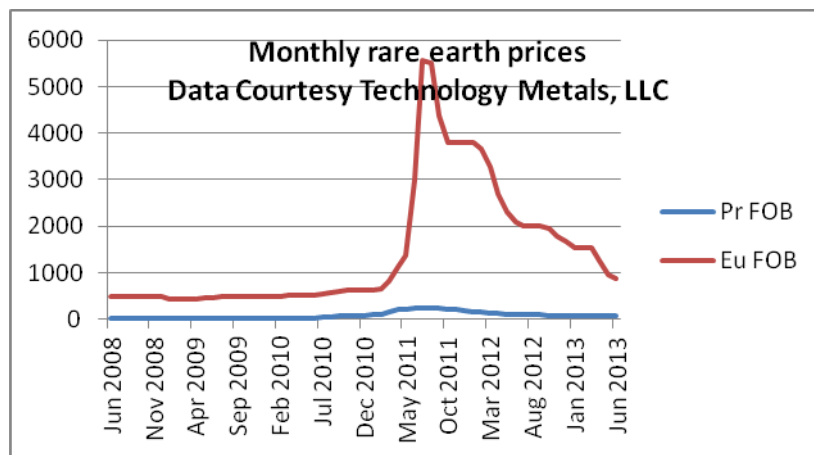


Figure 7: Monthly Rare Earth Prices.

Considering just europium (Eu) to begin with, both linear and an exponential trend lines seem to fit equally well, so both are shown in **Figure 8** with no prediction as to which trend line is the closer match. Also shown at left in **Figure 8** is the curve for the downward damped trend as the bubble has been bursting.

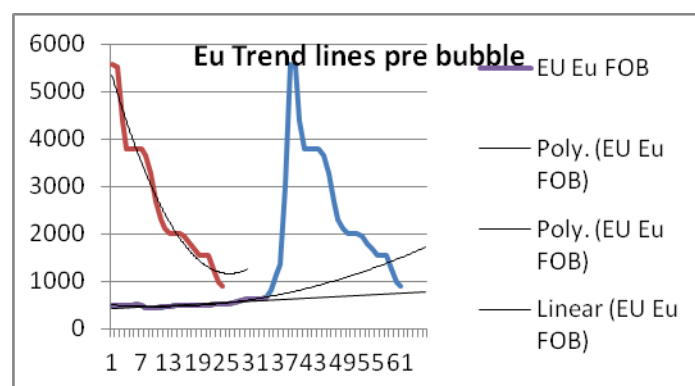


Figure 8: Rare Earth Pricing Predictions for Europium.

The reason for choosing europium is to see if non-commodity rare earth elements present a different pricing future compared with those used in commodities or consumer products. Many rare earths have uses in both markets; while europium is a toxic, reactive, rare element that has uses in a small number of applications including some that use its nuclear properties. For that reason, it is likely to have a growth market which is not strictly price



sensitive, and therefore may have an exponential trend line. The oscillation curve in **Figure 8** suggests that the prices have bottomed and should really be around \$1,200 - \$1,300 per Kg today instead of the \$880 it currently is. The maths (not shown) also suggests that if the growth trend is indeed exponential, the price will bounce back to a respectable \$2,000 within about 8 to 12 months. If the trend is more linear, the data suggests the prices are almost back to normal, but will continue to decrease for a similar period before returning to around \$1,000 per ton in less than a year. So that was the prediction for europium, that the price is undervalued and will settle at between \$1,200 and \$2,000 per Kg in about 8 months having dropped below their value and are about to bounce back.

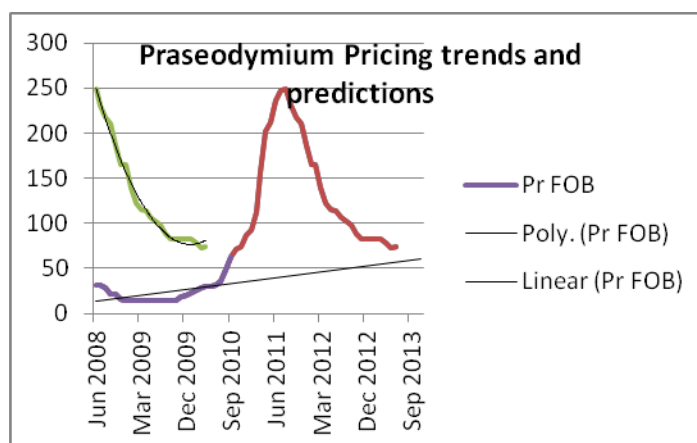


Figure 9: Rare Earth pricing bubble. Bloomberg.

The same exercise for Praseodymium in **Figure 9** suggests that Pr prices were about right in June 2013, that the prices had returning at a ‘critically damped’ rate to what they should be if the bubble had not occurred. This means that the price of Pr at \$74 per Kg then has bottomed out. The trend line equation (not shown) suggests the price of Pr will double about every 4 years from now.

Praseodymium applications are concentrated in the consumer products industries, glass works, filters, flints, and so on, and as such is more likely to follow a more linear and typical supply and demand character.

Another reason for choosing these two elements is that even though they are classified as one a heavy and the other a light, they are very close together in atomic number (59 and 63). So it is the technical difference of electron configuration that is making the difference in use and price more than the physical characteristics like weight, melting point or density.

In August 2014 the price of europium is \$1,000 per Kg and praseodymium is \$150 per Kg (**Figure 10**) showing that more than a year after the original analysis and forecast made in June 2013, the prices of these two rare earths is approximately as predicted (allowing for a linear curve for europium).

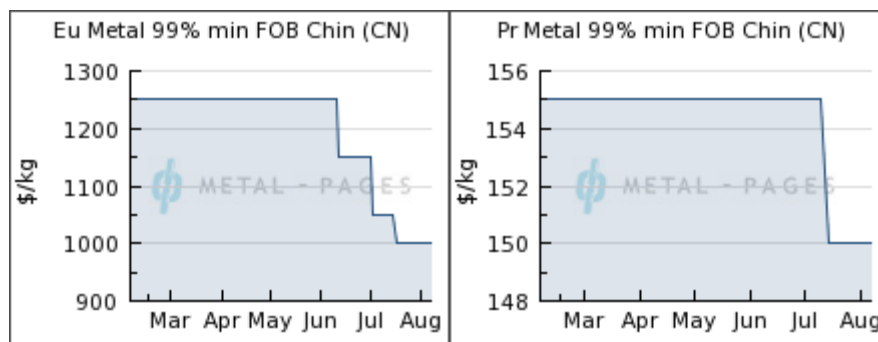


Figure 10. Current prices for europium and praseodymium (Metal-Pages) August 2014

Conclusion

The conclusion from this research is that the majority of rare earths are used in so called elastic markets. The failure of global rare earth prices to be as high as their reputation as critical ingredients to modern technological products is easily explained by fundamental supply and demand analysis as long as it is remembered that rare earths are concentrated in low cost consumer products markets which are resistant to high prices.

Price increases in elastic markets results in manufacturers looking for alternatives, which has happened in the rare earths industry with manufacturers seeking alternative supplier to China, with new manufacturers coming on line and with research to identify alternative components or to remove the component entirely.

During such a change of equilibrium, there can be a temporary price increase, which happened with rare earths in 2011, but which returns to pre price increase levels as the alternative activities generate results. The return is conveniently modelled as a damped oscillation which can be used to predict the time to stabilise and the new prices that rare earths will attract once the new equilibrium is reached.

Applying this to one heavy and one light rare earth, praseodymium (Pr) and europium (Eu) respectively, resulted in predictions in June 2013 that Pr will double in price about every 4 years and Eu will settle to between \$1200 and \$2000 per Kg within 8 months.



About Krucible Metals Limited:

Listed on Australia's main stock exchange since 2007, Krucible is an Australian-based resources company with an enviable history of discovery in phosphorus and rare earths as well as other elements. Krucible continues to explore for precious metals, base metals and strategic metals, and is transitioning to a combined exploration and mining company. Krucible has plans and expectations to ultimately enter joint ventures to develop mines on its tenements in the mineral rich Mount Isa area of Northwestern Queensland and elsewhere. Krucible has a strong industry-based board and management, who promote aggressive value-added mining projects.



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